Giant Mini-clusters as Possible Origin of "Halo" Phenomena Observed in Super-families

Brasil-Japan Collaboration of Chacaltaya Emulsion Chamber Experiment

ABSTRACT

Among 91 mini-clusters from 30 high energy Chiron-type families in Chacaltaya emulsion chambers, there are observed several extremely large multiplicity clusters in the highest energy range, far beyond the average of ordinary type clusters. We put the name giant mini-cluster for them. The present paper describes some details of microscopic observation of those giants mini-clusters in nuclear emulsion plates and some phenomenological regularity found in common among them. It is discussed such giant mini-clusters will be a possible candidate of origin of narrow symmetric single halo phenomena in X-ray films which is frequently observed in super-families of visible energy greater than 1,000 TeV.

1. Introduction

Since the observation of a super-family with a spectacular halo named "Andromeda" in Chacaltaya chamber no.14 in 1969, there have been a number of reports on observation of such halo phenomena from large scale mountain emulsion chamber experiments, and the existence of such halo is now considered to be a remarkable general characterisitics of cosmic-ray families of visible energy greater than 1,000 TeV. A halo is a general darkened area in X-ray films, ranging from several to several ten mm in diameter, in the central area of super-family. The microscopic observation in nuclear emulsion plates reveals that it is a bundle of great number of shower particles, hadrons and electron/gamma-rays. Since the frequency argument excludes the possibility that those halo phenomena are the results from ordinary type pion multiple production under the scaling rule starting from proton primary incidence, the origin of halo phenomena seems to suggest us new mechanism of particle production.

The recent observation of new shower phenomena named "mini-cluster" in Chacaltaya chamber shows unusual nature of shower particle production. It is a shower cluster which consists of hadrons and electron/gamma-rays with small spread, as small as $\langle E(\gamma)r \rangle$ a few several GeV.m, the same order of magnitude as young atmospheric cascade shower of electromagnetic origin. Among 91 mini-clusters in Chacaltaya chamber no.19, we found several huge mini-clusters with very large multiplicities in higher energy and larger $\langle Er \rangle$ ranges in mini-cluster statistics, far beyond the average of ordinary mini-clusters. The present paper describes some details of such huge mini-clusters, the giant mini-clusters, as the possible origin of halo phenomena in X-ray film observation.

2. Characteristics of huge shower core bundles

We present in Fig.1 the relation between $\Sigma E(\gamma)$ -N, total visible energy and multiplicity of shower cores with $E(\gamma) > 1$ Tev, and in Fig.2

$\langle Er \rangle$ -N, average spread and multiplicity, respectively, for all the observed 91 mini-clusters from 30 Chiron families in Chacaltaya chamber no.19[1] and one from no.18[2]. One sees most of the ordinary mini-clusters gathered around in small N and $\langle Er \rangle$ region and, at the same time, we find a group of shower clusters of large multiplicities, say $m > 30$, with large ΣE and $\langle Er \rangle$ values as indicated by the mark(◎). Since we see the multiplicity and spread of those clusters are significantly greater than the average of the ordinary mini-clusters, we separate them from the ordinary mini-clusters and put the name "giant mini-cluster" for them. Table 1 gives details of those selected giant mini-clusters.

Table 1. Some details of giant mini-clusters

Event no.	$\Sigma E(\gamma)$ (TeV)	N (>1 TeV)	$\langle r \rangle$ (mm)	$\langle Er \rangle$ (GeV.m)	family energy (TeV)
#174S-134I	1,056	158	2.88	10.00	1,164 (91 %)
#P06 (no.18)	961	123	1.77	7.40	1,272 (76 %)
#179S-126I	394	85	2.82	7.10	757 (52 %)
#174S-132I	270	98	2.84	4.80	342 (79 %)
# 93S- 56I	169	38	1.33	4.30	182 (93 %)
#165S-126I	126	30	1.79	5.73	156 (81 %)

Figures in bracket mean the energy fraction of giant mini-cluster to total visible family energy.

The following characteristics are remarkable to all the giant mini-clusters above selected. The first, they all show strong penetrative nature into lower chamber and we are able to see not small number of shower cores which could not be attributed to pure electromagnetic cascade originated from atmospheric electrons/gamma-rays. The second, shower bundles show small spread and extremely high rapidity density of number of shower cores in very narrow collimated region, as seen in Fig.3. Since the families are of very simple structure for all, the position of the origin of those giant mini-clusters is estimated to be near above the chamber, say less than 1 km or so. Microscopic observation in nuclear emulsion plates for central region of giant mini-cluster shows that there are none or very rare of scattered background electron tracks in space among shower cores. Especially, it is reported[2] that the central halo part of the event P06(no.18) is produced ~200 m above the chamber by the triangulation measurement. These facts show the unusual large rapidity density which reflects approximately just the initial state of the production as it is, not severely distorted by the multiplication due to atmospheric degradation. The third, these giant mini-cluster occupy the substantial part of family energy as shown in Table 1, different from the ordinary mini-clusters of Chiron families.

Fig.4 gives the distribution of Er of individual shower cores in giant mini-clusters. The shape of the distribution is the same among them and seems to be well expressed by common exponential law. The average values are given in Table 1.

3. Mini-clusters and giant mini-clusters

At present, we are not able to explain fully the exotic nature seen in either mini-cluster and giant mini-cluster from the present knowledge of the particle production. However, simultaneous observation of those two in the same Chiron family is very suggestive to explore the nature of giant mini-cluster.

At one glance, we immediately noticed that the giant mini-cluster is not of simple symmetrical structure but there are recognized a number of localized sub-clustering. And it is clear enough to hypothesize that giant mini-cluster will be an ensemble of mini-clusters. Then, here is presented the results of sub-clustering into mini-clusters by computer algorithm[3] where the constant is assumed to be Kc = 6 GeV.m, which corresponds to assume the giant mini-cluster be an ensemble of mini-clusters with the average spread $\langle Er \rangle = 1 \sim 2$ Gev.m. Fig.5 gives the distribution of E^*r^* of mini-clusters in giant mini-clusters of the present examples, together with the big halo events Ursa-Maior and M.A.III[4] as the reference, for both of them the detailed microscopic observation in nuclear emulsion plates was carried out. We see good regularity of the spread E^*r^* for all the present samples except the case M.A.III, which is wide spread halo in X-ray film observation. The average value is given as $\langle E^*r^* \rangle \simeq 30 \sim 50$ Gev.m. The hypothesis seems to be promising when we are required so rapid energy partition into a large number of minute low energy showers as is seen in experimental results.

4. Discussion

When we see two dimensional contour map of darkness of halo in X-ray films, we find varieties of core configuration. Some cases, it is of narrow single symmetrical core and the other cases, it is of multi-core structure. The event P06(no.18) is of clean single core halo in X-ray film observation, total darkness maximum of which is seen at $\sim$ 14 c.u. The shower clusters of event #174S-134I passes through the upper chamber before making a single definite halo in X-ray films. From these observation, single and narrow core halo in X-ray films seems to be nothing but huge shower clusters, the giant mini-cluster. When one looks multi-core events, like M.A.III, it seems it is an ensemble of the narrow single cores showing large spread as found in Fig.5.

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Reference

[1] Brasil-Japan Collaboration ; this issues HE 3.5-3.

[2] N.M.Amato, N.Arata and R.H.Maldonardo ; Proc. Intern. Symp. on Cosmic-Rays and Particle Physics (1984) 123

[3] H.Semba ; Suppl. Prog. Theor. Phys. no.76 (1983) 111

[4] S.Yamashita ; Jour. of the Phys. Soci. of Japan Vol.54 No.2(1985) 529

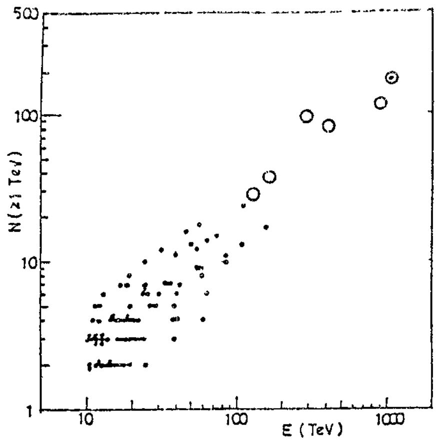

Fig.1 Relation between energy sum, E, and multiplicity, N(>1TeV), of shower cores in mini-clusters.
⊙: giant-mini-clusters (Table 1)

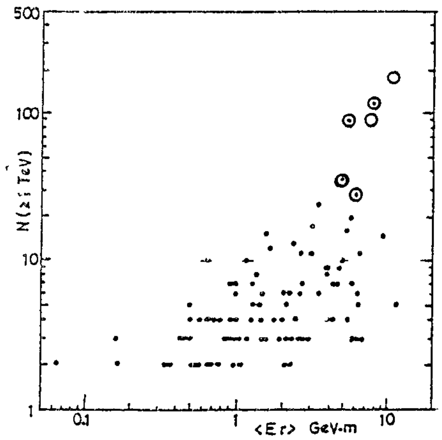

Fig.2 Relation between average spread, <Er>, and N(>1TeV) of shower cores in mini-clusters.
⊙: giant-mini-clusters.

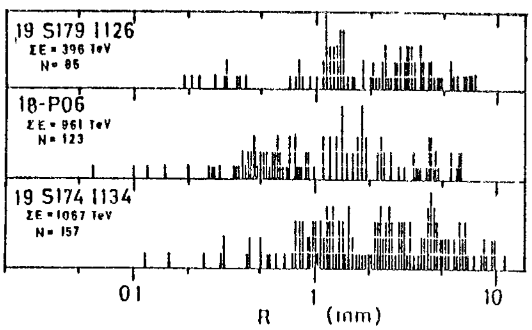

Fig.3 Log r -plot for shower cores of giant-mini-clusters.

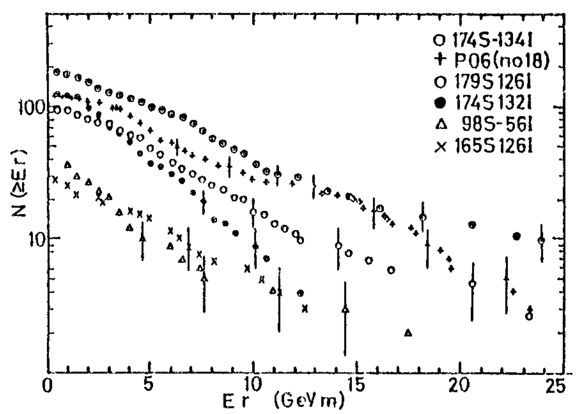

Fig.4 Integral distribution of Er of shower cores in giant-mini-clusters.

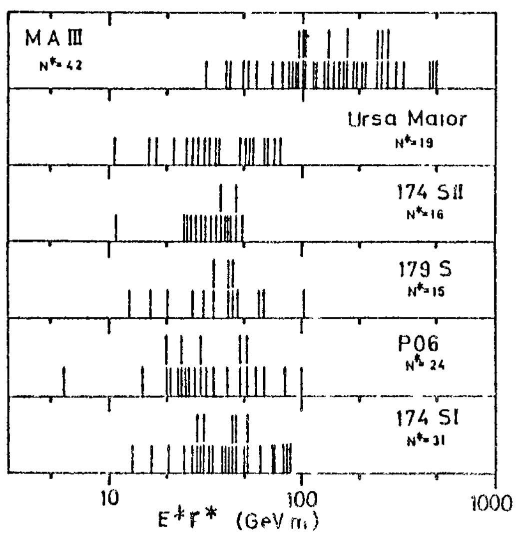

Fig.5 Distribution of $E^{*}r^{*}$ of mini-clusters in giant-mini-clusters and huge core bundles of halo in super-families Ursa-Maior and M.A.III.